

1 Title: Downhole Drill String Having a Collapsible Subassembly

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4 This application claims priority to pending US Provisional Patent Application
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7 **BACKGROUND OF THE INVENTION**

8 The present invention relates to an apparatus and method for loosening a stuck
9 section of a downhole drill string within a well borehole. More particularly, but not by way
10 of limitation, the present invention relates to collapsing a subassembly along a section of a
11 rotatable drill string to reduce the subassembly's outside diameter while at the same time
12 initiating within the string a jarring action or force that resonates along the entire drill string
13 and simultaneously allowing drilling fluid inside the drill string to circulate to the outside of
14 the string within the well borehole. All of the structural features and actions of the present
15 invention cooperate to collapse a sub-section of the drill string allowing upstream sections to
16 continue to rotate within the borehole. The collapsing subassembly may be a drilling
17 stablizer, a reamer, or even a casing scraper. In some applications, the collapsing
18 subassembly need not be stuck to activate the natural jarring actions and the circulating
19 features of the present invention.

1 A drill string is used to drill a subterranean well bore. The drill string typically
2 consists of multiple joints of drill pipe, drill collars, and a drill bit. To facilitate completion
3 of the well, it is important that deviation from vertical be controlled. In the past, deviation of
4 the well bore has been controlled by the manipulation of the string weight on the drill bit or
5 directional control tools, such as mud motors and monel collars. The length, weight, and
6 outside diameter of the drill collars help maintain stabilization while applying a sufficient
7 amount of weight on the bit to affect bit penetration. However, too much weight on the bit
8 may result in hole deviation problems.

9 Additional equipment has been used to stabilize the drill string. These devices are
10 commonly known as stabilizers. These tools have a larger outside diameter than the drill
11 collars and are in constant rotational contact with the sidewall of the well bore during the
12 drilling process. The problem with stabilizers is that the contact between the stabilizer and
13 the well bore can be the source of many problems. For example, penetrated, soft formations
14 may collapse or swell inwardly after penetration of the bit which may in turn cause the
15 stabilizer to become stuck. In addition, water loss in some formations may cause excessive
16 mud cake buildup on the wall of the well bore which can also cause sticking to occur.

17 There are times when other subassemblies other than stabilizers get stuck, slowing or
18 stopping the drilling process. Sometimes reamers which are cutting a larger bore above the
19 drill bit bore become lodged in the walls of the formation. Occasionally, a casing scraper
20 used to clean an in place casing run also becomes stuck within the casing. These problems

1 are tremendously costly to correct with current technology. Often the drill string must be left
2 downhole and the well bore redrilled.

3 Further, if a subassembly does become stuck, this can lead to the drill string
4 becoming stuck in several additional locations along the string if rotation of the drill string
5 and circulation of drilling fluid is not maintained. The present invention allows the stuck
6 subassembly to cease rotating while the sections above the stuck one continue to rotate.
7 Further, it may be difficult to free the drill string from being stuck if the point of sticking is
8 not known, and the process of determining the sticking point is expensive and time
9 consuming.

10 To this end, a need exists for a subassembly that is capable of being selectively
11 collapsed to reduce its outside diameter if the sub becomes stuck thereby possibly
12 eliminating the point of sticking. A need further exists for a drill string that is capable of
13 maintaining circulation and rotation above the point of sticking to prevent further sticking of
14 the drill string. Further, there is a need to be able to jar the string internally when stuck, and
15 to be able to locate where along the string the subassembly is stuck. It is to such an
16 apparatus that the present invention is directed.

17 **BRIEF DESCRIPTION OF THE DRAWINGS**

18 Fig. 1A is an elevational view, partly in cross section, showing a drill string
19 constructed in accordance with the present invention installed in a well bore in a drilling
20 position with an upstream pipe section attached to the subassembly and showing a bit.

1 Fig. 1B shows a lower portion of the subassembly of the present invention in the drilling
2 mode from the bit crossover section to above the spacer mandrel without showing a bit or the
3 well bore. Fig. 1C shows an upper portion of the subassembly of the present invention in the
4 drilling mode from the leaf barrel to the mandrel top sub without showing the upstream drill
5 string section on the well bore.

6 Fig. 2A illustrates an elevational view, partly in cross section, showing the drill string
7 in the released position with the drill string left off the bottom of the well bore. Fig. 2B
8 shows a position of the subassembly of the present invention in the released mode from the
9 bit crossover section to leaf barrel. Fig. 2C shows a portion of the subassembly of the
10 present invention in the released mode from the leaf barrel to the mandrel top sub.

11 Fig. 3A is a partial, cutaway, isometric view of a bit crossover. Fig. 3B is an
12 elevational view, partially in cross section, of the bit crossover.

13 Fig. 4A is a cutaway, isometric view of a circulating sub. Fig. 4B is an elevational
14 view, partially in cross section, of the circulating sub.

15 Fig. 5 is an isometric view of a spline housing.

16 Fig. 6 is an isometric view of another embodiment of a spline housing.

17 Fig. 7 is a cutaway, isometric view of a spacer housing.

18 Fig. 8A is an isometric view of a leaf barrel. Fig. 8B is a cutaway, isometric view of
19 the leaf barrel. Fig. 8C is a cross-sectional view taken along line 8C-8C of Fig. 8A.

1 Fig. 9A is an isometric view of a centralizing leaf. Fig. 9B is a side elevation view of
2 one of the centralizing leaves.

3 Fig. 10 is an isometric view of a trip ring. Fig. 10B is an elevational view, partially
4 in cross section, of the trip ring.

5 Fig. 11 is a cutaway, isometric view of a trip ring retainer.

6 Fig. 12A is a cutaway, isometric view of a mandrel. Fig. 12B is an elevational view,
7 partially in cross section, of the mandrel. Fig. 12C is a detail view of the trip ring and anvil
8 taken from A in Fig. 12A.

9 Fig. 13A is an isometric view of a spacer mandrel.

10 Fig. 14A is a cutaway, isometric view of a spline mandrel. Fig. 14B is an elevational
11 view, partially in cross section, of the spline mandrel. Fig. 14C is an end view of the spline
12 mandrel taken along line 14C-14C of Fig. 14.

13 Fig. 15A is a cutaway, isometric view of a stinger. Fig. 15B is a split, elevational
14 view, partially in cross section, of the stinger.

15 Fig. 16 is an elevational view of another embodiment of a drill string containing a
16 plurality of stabilizers constructed in accordance with the present invention.

17 **DETAILED DESCRIPTION OF THE INVENTION**

18 Referring to Figs. 1A and 2A, a portion of a drill string 10 constructed in accordance
19 with the present invention, is shown incorporated in an overall drill string 12 located
20 downhole within a well bore hole 14. Although a single section 10 is illustrated as being

1 attached to the string 12 between drill collar 16 and drill bit 18, it should be understood that
2 single or multiple sections may be attached to the string 12 as discussed below.

3 Fig. 1A illustrates the string 12 in a drilling mode with the weight of the drill string
4 12 applied to the bit 18 and the entire string 12 being rotated by a drilling rig (not shown) or
5 the bit 18 may be independently rotated by a mud motor. In the drilling mode, a collapsing
6 subassembly 11 engages the side wall of the well bore 14 to maintain a substantially vertical
7 orientation. In Fig. 1A, the subassembly 11 is a stabilizer wherein leaves 34 are extended
8 against the sidewall. As previously stated, the leaves 34 may be replaced by a reamer or
9 scraper mechanism.

10 Fig. 2A shows the string 12 in a non-drilling mode wherein the subassembly 11 has
11 been tripped, the leaves 34 have collapsed to a release position away from the sidewalls, and
12 the subassembly longitudinal extended initiating an internal jarring action within the drill
13 string and circulation of drilling fluid via holes 72 from inside the subassembly 11 to outside
14 the subassembly and into the well bore hole, and allowing for continued rotation of the drill
15 string sections above the tripped subassembly.

16 The subassembly 11 includes a housing assembly 20 and a mandrel assembly 22 that
17 is adapted for telescopic movement relative to the housing assembly 20. The housing
18 assembly 20 includes a bit crossover 24, a circulating sub 26, a spline housing 28, a spacer
19 housing 30, a leaf barrel 32, a plurality of centralizing leaves 34, and a trip ring retainer 36.

1 The mandrel assembly 22 includes a mandrel top sub 23, centralizing mandrel 82, a spacer
2 mandrel 84, a spline mandrel 86, and a stinger 88.

3 Turning to Figs. 1B and 1C, the bit crossover 24 has an external threaded portion 38
4 for connection with the drill bit 18 or another member of the drill string 12, such as a drill
5 collar. The crossover 24 is provided with an annular recess 40 for receiving the stinger 88
6 portion of the mandrel assembly 22, as discussed below, and a second threaded portion 39
7 for connection with the circulating sub 26. Additionally, it should be understood that the bit
8 crossover 24 may be provided with a plurality of circulating parts (not shown) and a sliding
9 sleeve activated by a drop bar to facilitate circulation of drilling fluid without the need to
10 move the subassembly 11 to the released position.

11 The circulating sub (Figs. 4A and 4B) is provided with a plurality of holes 42 to
12 permit the release of drilling fluid when the subassembly 11 is in the released condition. The
13 holes 42 may be provided with accessories, such as check valves or tungsten inserts. The
14 circulating sub 26 is further provided with a plurality of annular grooves 44 for receiving an
15 O-ring and a pair of grooves 46a for receiving seal members, such as a polypak type seal.
16 The upper end of the circulating sub 26 is provided with an internal shoulder 47 for
17 supporting a jarring wear ring 49. The upper end of the circulating sub 26 is connected to
18 the spline housing 28.

19 The spline housing 28 is provided with a plurality of involute splines or teeth 48
20 extending longitudinally along the interior surface of the spline housing 28. Fig. 6 illustrates

1 another embodiment of a spline housing 28a having a plurality of equi-spaced splines or
2 teeth 48a. The upper end 23 of the spline housing is connected to the spacer housing 30.

3 As shown in Fig. 7, the spacer housing 30 is an elongated tubular member having a
4 bore 50. Each end of the spacer housing 30 is provided with an annular groove 52a and 52b
5 for receiving an O-ring. The upper end of the spacer housing 30 is connected to the leaf
6 barrel 32.

7 As shown in Figs. 8A through 8C, the leaf barrel 32 is provided with an internal
8 shoulder 56 for supporting another wear ring 49 (see Fig. 4B). The upper end of the leaf
9 barrel 32 is provided with an annular recess 80 for receiving a trip ring 81 (Fig. 10A). The
10 leaf barrel 32 further includes a plurality of elongated slots 58 spaced circumferentially about
11 the leaf barrel 32. The slots 58 are adapted to receive one of the centralizing leaves 34 so that
12 the centralizing leaves 34 are moveable through the slots 58 in a radial outward and inward
13 direction, as will be discussed in greater detail below. The slots 58 are interrupted at medial
14 locations by one or more bridges 77.

15 As shown in Figs. 9A and 9B, each of the centralizing leaves 34 has a first end
16 portion 60 and a second end portion 62 which are adapted to be disposed in corresponding
17 recesses 64 and 66 of the leaf barrel 32 (Fig. 8B). Each centralizing leaf 34 is provided with
18 a wall engaging portion 68 which is formed at a medial portion of the leaf 34. The external
19 side of the wall engaging portion 68 is provided with a plurality of arcuate shaped grooves
20 70 to facilitate sliding engagement with the sidewall of the well bore 14 and permit fluid

1 passage. It will be understood that the size and shape of the wall engaging portion 68 of the
2 leaf 34 may be formed in a variety of shapes depending on the functional requirements. For
3 example, the wall engaging portion 68 can be configured to function as a reamer or a casing
4 scraper.

5 The interior side of each centralizing leaves 34 is provided with a cam surface 72.
6 The centralizing leaves 34b are provided with medial grooves 78 adapted to receive the
7 bridges 77 of the leaf barrel 32a to stabilize the centralizing leaves 34b in the expanded
8 condition.

9 The trip ring 81 (Fig. 10A) is retained in the annular recess 80 of the leaf barrel 32
10 (Fig. 8B) by the trip ring retainer 36, best shown in Fig. 11.

11 Referring again to Figs. 1-1B and 2-2B, the housing assembly 20 forms a housing for
12 the mandrel assembly 22 which is adapted for telescoping movement relative to the housing
13 assembly 20 between a drilling position and a released position. In the drilling position, the
14 mandrel assembly 22 is positioned to force the centralizing leaves 34 of the subassembly 11
15 to move to the expanded position and to transfer torque applied to the mandrel assembly 22
16 by a drilling rig (not shown) to the housing assembly 20 and in turn to the drill bit 18. In the
17 released position, the mandrel assembly 22 allows the centralizing leaves 34 to move to the
18 collapsed position, creates a jarring action (within the drill string portion 10) to the housing
19 assembly 20 upon being released from the drilling position, is capable of rotating freely
20 relative to the housing assembly 20, and permits fluid circulation through the drill string 12

1 to be uninterrupted. To facilitate these functions, the mandrel assembly 22 includes a
2 mandrel 82, a spacer mandrel 84, a spline mandrel 86, and a stinger 88.

3 As shown in Figs. 12A and 12B, the mandrel 82 has an internal bore 90 extending
4 therethrough from an upper end 83 to a lower end 89. The upper end 83 of the mandrel 82 is
5 provided with internal threads 91 for connection with a drill collar or drill pipe. Telescopic
6 movement of the mandrel 82 relative to the centralizing leaves 34 causes the centralizing
7 leaves 34 to move between the expanded position and the collapsed position. To affect the
8 movement of the centralizing leaves 34 to the expanded position, the mandrel 82 is provided
9 with a cam surface 94 near the lower end 89 thereof. The cam surface 94 cooperates with the
10 cam surface 72 of the centralizing leaves 34 to force the centralizing leaves 34 radially
11 outward to the expanded position upon telescopic contraction of the mandrel 82 into the
12 housing assembly 20. Upon telescopic expansion of the mandrel 82 from the housing
13 assembly 20, the elasticity of the centralizing leaves 34 causes the centralizing leaves 34 to
14 return to the collapsed position. Contact of the centralizing leaves 34 with the sidewall of
15 the well bore 14 may assist in returning the centralizing leaves 34 to the collapsed position.

16 The mandrel 82 is further provided with an annular recess 96 sized to hold the trip
17 ring 81 (Fig. 10A) so as to restrain longitudinal movement of the mandrel assembly 22
18 relative to the housing assembly 20 in the drilling position. The trip ring 81 is fabricated to
19 be released from the annular recess 96 upon the application of a longitudinal pulling force on
20 the drilling string 12 which translates into a predetermined axial force in the ring. The axial

1 forces created in the trip ring 81 are determined by the length of the ring L; the thickness of
2 the ring T; and, most significantly, the angle A of the trip ring edges and the angle of the
3 shoulder 97 of the annular recess 96 of mandrel 82. As will be described in more detail
4 below, the pulling force required to overcome the predetermined axial force to "open" the
5 trip ring 81 may be varied to provide an indication of where the drill string 12 is stuck in the
6 well bore hole. It should further be appreciated that other retaining members can be used in
7 place of a trip ring. For example, the housing assembly 20 may be provided with a friction
8 grip collet quick release device which is adapted to mate with a corresponding recess in the
9 mandrel 82. Other friction trips or shear pins may be used, but one time trips have the
10 disadvantage of requirement the drill string 12 to be withdrawn from the well hole. Fig. 12C
11 illustrates the details of the trip ring operation.

12 The lower end 89 of the mandrel 82 is connected to the upper end 93 of the spacer
13 mandrel 84 (Figs. 13). The upper end of the spacer mandrel 84 is provided with a groove 98
14 to receive an O-ring so as to provide a fluid tight seal between the spacer mandrel 84 and the
15 mandrel 82. The lower end 101 is also provided with an annular groove 100 or receiving an
16 O-ring. The spacer mandrel 84 has an internal bore 102 extending from the upper end 93 to
17 the lower end 101.

18 The lower end 101 of the spacer mandrel 84 is connected to an upper end 103 of the
19 spline mandrel 86 (Figs. 14A-14C). The spline mandrel 86 is provided with an internal bore
20 104 extending from the upper end 103 to the lower end 107 thereof. The external surface of

1 the spline mandrel 86 is provided with a plurality of splines or teeth 105 extending
2 longitudinally along the external surface thereof. The splines 105 are sized and shaped to
3 mate with the splines 48 of the spline housing 28 when the subassembly 11 is in the drilling
4 position and thereby transmit rotational torque applied to the mandrel assembly 22 to the
5 housing assembly 20. When the subassembly 11 is moved to the released position, the spline
6 mandrel 86 is in a non-engaging position relative to the spline housing as shown in Figs. 2A-
7 2B. As such, the mandrel assembly 22 is capable of being rotated relative to the housing
8 assembly 20. If the housing assembly 20 is stuck, that portion of the drill string 12 extending
9 above the housing assembly 20 may be rotated and hereby prevent additional portions of the
10 drill string 12 from becoming stuck. To further facilitate rotation of the mandrel assembly
11 22 relative to the housing assembly 20, the housing assembly 20 may be provided with load
12 bearings (not shown) at the upper and lower ends of the leaf barrel 32 to centralize rotation
13 of the mandrel assembly 22 and reduce friction.

14 The ends 120 of the splines 105 are beveled to facilitate engagement with the spline
15 housing 28 when the mandrel assembly 22 is moved from the released position to the drilling
16 position. The beveled ends of the splines 105 additionally prevent damage to the splines 105
17 upon the mandrel assembly 22 being released from the drilling position. That is, upon the
18 release of the mandrel assembly 22 from the drilling position as a result of a pulling force
19 being applied sufficient to overcome the tripping force of the trip ring 81, the mandrel
20 assembly 22 travels upwardly until the upper end 103 of the spline mandrel 86 impacts the

1 wear ring 49 thereby producing a hammer type action within the subassembly 11 that may
2 loosen or free the stuck drill string. The beveled ends 120 of the splines 105 also prevent
3 damage to the splines 104 when the mandrel assembly 22 is moved to the drilling position.
4 Upon initial engagement of the spline mandrel 86 with the spline housing 28, the drill string
5 12 may be lowered to cause the lower end of the spline mandrel 86 to impact the adjacent
6 wear ring 49 and produce a downward hammer type action that may loosen or free the stuck
7 drill string.

8 To further prevent damage to the spline mandrel 86, the wear rings 49 are preferably
9 fabricated of a material that is softer than the material from which the spline mandrel 86 is
10 fabricated. Consequently, only the wear rings 49 need be replaced after each use of the
11 subassembly 11, rather than the spline mandrel 86.

12 The lower end 107 of the spline mandrel 86 is connected to an upper end 122 of the
13 stinger 88. The stinger 88 (Figs. 15A and 15B) is an elongated pipe with an internal bore
14 106 extending from the upper end 122 to the lower end 124 thereof. The upper end 122 of
15 the stinger 88 is provided with an annular groove 108 for receiving an O-ring so as to form a
16 fluid tight seal between the upper end of the stinger 88 and the lower end of the spline
17 mandrel 86. The lower end of the stinger is provided with a pair of annular grooves 110 for
18 receiving seal members 111 (Figs. 1 and 2) which are preferably pressure activated and
19 which are capable of rotational sealing. The stinger 88 has a length such that the lower end
20 124 of the stinger 88 is positioned in the annular recess 40 of the bit crossover 24 when the

1 subassembly 11 is in the drilling position. With the lower end of the stinger 88 positioned in
2 the annular recess 40 of the bit crossover 24, the seal members 111 form a fluid tight seal
3 between the stinger 88 and the bit crossover 24 thereby providing a fluid conduit extending
4 through the mandrel assembly 22 and through the bit crossover 24 to permit circulation to
5 the drill bit 18.

6 When the mandrel assembly 22 is moved to the released position, the lower end of
7 the stinger 88 is positioned above the holes 42 of the circulating sub 26. As such, if the drill
8 bit 18 is plugged or if a plug is inserted into the upper end of the bit crossover 24, drilling
9 fluid is capable of being circulated through the mandrel assembly 22 and out through the
10 holes 42 of the circulating sub 26. It should be noted that the internal diameter of the
11 circulating sub 26 is greater than the outer diameter of the seal members 111 of the stinger
12 88 such that the seal members are in a non-compressed state which the mandrel assembly 22
13 is traveling between the drilling position and the released position. However, substantial
14 circulation of drilling fluid to the drill bit 18 is again initiated upon the lower end of the
15 stinger 88 being lowered below the holes 42 of the circulating sub 26.

16 Referring now to Fig. 16, a drill string 12 that includes stabilizers 10a, 10b, and 10c
17 is illustrated. As previously stated, the subassembly 11 may be stabilizers 10a, 10b, and 10c;
18 or, alternatively, a reamer or casing scraper. In Fig. 16, the stabilizer 10a is located adjacent
19 to a drill bit 18a with the stabilizers 10b and 10c shown to be spaced at approximately thirty
20 to sixty foot intervals. The stabilizers 10a-10c are each provided with a trip ring 81 which is

1 designed to release at different preset pulling forces. For example, the stabilizer 10a may be
2 provided with a trip ring designed to release upon the application of a pulling force of 20,000
3 pounds above drill string weight, while the trip ring of the stabilizer 10b is designed to
4 release at 40,000 pounds above drill string weight, and the trip ring of the stabilizer 10c is
5 designed to release at 60,000 pounds above drill string weight.

6 By utilizing stabilizers or any collapsing subassembly in the drill string with different
7 trip settings, the approximate location that the drill string 12 is stuck may be determined. If
8 the drill string 12 becomes stuck and upon applying a pulling force of at least 20,000 pounds
9 above drill string weight, and the stabilizer 10a releases, then it can be concluded that the
10 drill string 12 is stuck at the housing assembly of the stabilizer 10a or lower. Likewise, if a
11 pulling force greater than 40,000 pounds above drill string weight is required to release one
12 of the stabilizers, then it can be concluded that the drill string 12 is stuck below the stabilizer
13 10a and the stabilizer 10b. Finally, if a pulling force of 60,000 pounds above drill string
14 weight is required to release one of the stabilizers, then it can be concluded that the drill
15 string 12 is stuck between the bit 18a and the stabilizer 10c. With the location of the sticking
16 point identified, an appropriate treatment can be more easily designed and implemented.

17 Although the invention has been described with reference to specific embodiments,
18 this description is not meant to be construed in a limited sense. Various modifications of the
19 disclosed embodiments, as well as alternative embodiments of the inventions will become
20 apparent to persons skilled in the art upon the reference to the description of the invention. It

- 1 is, therefore, contemplated that the appended claims will cover such modifications that fall
- 2 within the scope of the invention.